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John A. Ananian et al.	Our Docket No.	:
Serial No.	: 09/632,383	Group Art : 2166
Filed	: August 3, 2000	Examiner : Srirama T. Channavajjala
For	: GENERATING CAD INDEPENDENT INTERACTIVE PHYSICAL DESCRIPTION REMODELING, BUILDING CONSTRUCTION PLAN DATABASE PROFILE	

## MAIL STOP ISSUE FEE

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**Enclosed in this fax transmittal are the following items:**

1. PART B – FEE(S) TRANSMITTAL FORM for application # 09/632,383.
2. CREDIT CARD PAYMENT FORM for issue fee.
3. Reference for Inclusion (13 pages in total)

Serial No. 09/632,383

**COMMUNICATION:**

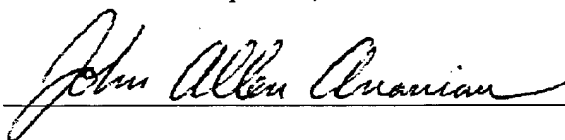
Subject to Applicant's continuing duty of disclosure, Applicant submits herewith a copy of the reference listed below.

1. Faraj et al., "Integrated Design Construction System Support System: The WISPER Approach," dated February 17, 2000

This reference was cited in an office action dated more than three months ago in a corresponding Korean application, and thus the time period for filing an IDS requesting consideration of this reference by the USPTO has expired. Nevertheless, applicant submits the reference for inclusion in the USPTO file for this application. Submission of this reference is not an admission of materiality, or of the date of the reference. The reference is 13 pages in total.

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John Allen Ananian  
Date of Signature: April 21, 2005

Respectfully submitted,  
John Allen Ananian



NewerHome Technologies, Inc.  
8029 Northwind Drive  
Lantzville, B.C. V0R 2H0  
Canada

Telephone: (250) 390-3585  
Facsimile: (250) 390-3595  
john@newerhome.com

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## INTEGRATED DESIGN-CONSTRUCTION SUPPORT SYSTEMS: THE WISPER APPROACH

I. FARAJ

*Centre for Construction IT, Building Research Establishment*

AND

M. ALSHAWI, G. AOUAD

*Department of Surveying, University of Salford*

AND

T. CHILD

*Design Technology, Salford, UK.*

AND

J. UNDERWOOD

*Department of Civil Engineering, Leeds University, UK.*

**Abstract.** Collaborative working in construction is becoming a reality as many activities are performed globally with actors located in various geographical locations. This paper discusses the development and implementation of a Web-based collaborative working environment, namely 'WISPER' which has been developed at the University of Salford. WISPER allows the exchange of project data between different parties of the construction sector. The environment is based on a three tier architecture, where user interfaces, business logic and database are kept separate. WISPER has used the state of the art technologies and standards such as CORBA and IFC. The system has been implemented using an object-oriented database which communicates with construction applications using client-server technologies. The user scenario of the integrated environment was captured through the 'Use Cases' technique. Six use cases have been identified and presented in this paper. The first use case describes how the system establishes a new project database and its associated set of web pages. The populating a database with design information is discussed in use case 2. Use case 3 reports on how all the building elements that form the design and the number of occurrence of each element can be made available to the user to be costed. Use Case 4

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describes the user requirement to view building elements through a standard VRML and DWF capable web browser. The requirement of the planner to program tasks associated with building elements is reported in Use Case 5. Finally, use case 6 captures the requirement for a functionality to allow a designer to access data sheets on any building elements in a design. The implementation of each use case is also reported.

## 1. Introduction

The support for the design and construction procedures of a construction project has been studied in terms of intelligent CAD/CAC. In our research, a Web based Computer integrated environment have been developed in order to realise effective support to the design/construction processes performed by a group of expert practitioners involved in a construction project. In previous works (Alshawi et al. 1998; Faraj et al. 1998a, 1998b) we have reported on the design and construction models and applications and their implementations in order to provide intelligent support to the project practitioners by developing a more intuitive user interfaces to a new generation of computer integrated environments that reflects cognitive activities of the experts in the construction projects. In this paper we have presented the users views and scenarios and the functionality required from such environment.

First, the design-construction support systems have been integrated into a computer integrated environments for construction; namely WISPER (Web-based IFC Shared Project Environment) have been presented. These systems take full advantage of the functionality of the VR and other Web technologies such as WHIP and HTML to provide easy perception and understanding of what is being presented, and direct manipulation. Second, development of applications that enable the construction team which may well be dispersed over a number of physical geographical places to share and exchange data in a manner which is totally transparent to them.

## 2. Motivation

In any construction project many practitioners of different expertise such as architects, structural engineers, quantity surveyors, suppliers, etc are involved in a one-of-a-kind project which would require cooperation and coordination. Any reasonable size construction project consists of a number of organisations and teams which are brought together for duration of that particular project to form, so called a "virtual enterprise" and would change with each project. This virtual enterprise is often contains units that have

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different backgrounds and may vary in physical location and computer platforms and has a need to work collaboratively and share project data among the various teams. These issues have been considered in the development of design-construction support systems.

According to our review of computer integrated environments in the construction domain, the basic structure of such environments can be conceptually summarised as the show in Figure 1. The figure shows the basic components required in a typical environment. It may consist of design model and other construction model (together they form a product model), application interfaces, construction application that read from and write data to the product model and the user interface to enable users to interact with the environment. Development of such environments would enable users to work concurrently and share project information in real time. Models usually are implemented as a computerised database that can be used by construction applications which can be distributed to accomplish the various construction tasks required during the project lifecycle.

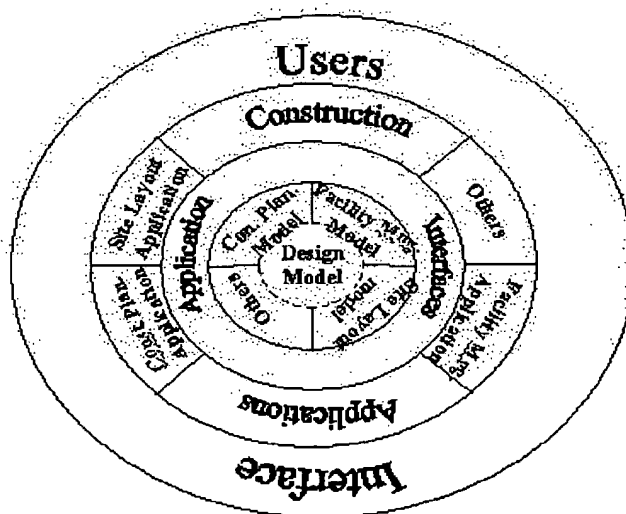


Figure 1: A conceptual representation of a computer integrated environment

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### 3. Development of a Computer Integrated Environment – Framework

The environment is implemented as three tier architecture which separates data processing (client) from interface (applications or web server) and data storage (database server).

Designs can be created using a CAD system. The CAD system is capable of writing to and reading data from Part 21 files that conform to IFC v1.5 schema. Once the design is created its Part 21 file can then be loaded to the database through the user interface.

The user interface can be used to pass and retrieve processed data associated with the project. Different construction experts use different tools to view or process the data, the environment supports a number of these tools.

The interface uses HTTP protocol to communicate with the web server. The web server delegates the responsibility for processing the HTTP requests to the CORBA objects which can then invoke the relevant application to process the data and return the result to the user in a format that can be viewed and understood by the construction expert. For example, costing will be displayed on Excel spreadsheet or planning data is returned to be viewed on MS Project. The implementation of the framework is described in more details in (Faraj et al. 1998a).

#### 3.1 RATIONAL

- It is currently believed that information integration should be based on a project model, a repository for the shared information created and used during the complete project life cycle. Therefore, in the implemented environment, the form and content of the data structures used to represent project information is based on the IFC project model developed by the IAI.
- A typical construction project consists of a number of organisation and teams which are brought together for duration of that particular project to form, so called a "virtual enterprise" and would change with each project. This virtual enterprise is often contains units that vary in physical location and computer platforms and has a need to work collaboratively and share project data among the various teams. The Internet with its open standards and accessibility is fast evolving into a powerful environment for supporting distributed collaborative work. This work recognises this reality and takes advantage of open Internet standards wherever possible.
- To enable construction organisations manage and retain full control of their data, a complete separation of the databases from the users is required. It is only the application server, i.e. the middle tier, that can access the database server and all user requests go through the

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application server. Moreover, the bulk of the complex code resides in the application server in the form of objects and this makes the system easier to maintain, modify and improve. Therefore, applications were implemented as a web servers which can be distributed through out the network. However, user can access the applications with the need to know about the physical locations of the applications.

- To enable the adaptation of such environment by industry, the user interface was developed as set of Web pages, which the user can access from any web browser. Standard off-the-shelf software tools such as spreadsheets and construction planning software were used to display and manipulate data by the user.

### 4. Development of a Computer Integrated Environment – Users' Scenarios

This section presents the use cases that resulted from meeting with group of construction professionals that are likely to use such environment in their practice. Use cases is a technique for eliciting, understanding and defining functional system requirement. Developing software is normally a process of interaction between a procurer and a developer. It is vital that during this process both sides talk the same language for how the system to be developed should work or be used. Use Cases explores the critical requirements to be met by the system. They are presented as text that describes the interaction between the user and the system to be developed. A use case is a specific way of using a system i.e. some functionality is performed by the system in response to a stimulus from an actor (human or software). They provide a vehicle to (Rational Rose 1998):

- Capture the requirements about the system.
- Communicate with end users and domain experts.
- Test the system.

The description of a use case defines what happens in the system when the use case is performed; it corresponds to a sequence of transaction performed by the system, which yields a measurable result to a particular actor.

During the development of this project a number of use cases have been identified. The use cases below are intended to capture user-oriented interactions with the working system (Jacobson 1998).

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#### 4.1 CASE 1 - ESTABLISHING A NEW PROJECT DATABASE

This case describes how the system establishes a new project database and its associated set of web pages. System interaction is as follows:

- a) The user accesses a web page containing a form with fields for specifying the information needed to initialise a new project database e.g. project participants, location, client information etc. To access this page the user is required to enter a user name and password.
- b) The user fills in the form and submits it to the web server.
- c) The system creates a standards set of project web pages containing links to access design, estimating and planning information for the project.
- d) The system creates the project database and populates it with a minimal set of project information derived from the submitted form.

#### 4.2 CASE 2 - POPULATING A DATABASE WITH DESIGN INFORMATION

This case describes the population of the project database with information from an IFC compatible CAD system e.g. AutoCAD/AEC-6. The exchange will be achieved through the IFC flat file format, as this will be supported by all of the emerging IFC compatible CAD systems. System interaction is as follows:

- a) The designer accesses and logs in to the project web site using a standard web browser.
- b) The designer navigates to the design web page and is presented with a choice to retrieve all or part of the design.
- c) The designer uses the IFC import function of the CAD system on the generated file.
- d) The designer uses the facilities of an IFC compatible CAD systems to manipulate the part of the design they are currently working on.
- e) The designer uses the IFC export function of the CAD system to generate a STEP physical containing the amended design.
- f) The designer invokes a program to upload the design to the project server.

#### 4.3 CASE 3 - COST ESTIMATING

All the building elements that form the design and the number of occurrence of each element will be made available to the user to be costed. System interaction is as follows:



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- a) The estimator accesses and logs in to the project web site using a standard web browser.
- b) The estimator navigates to the cost estimating web page and is presented with a choice to retrieve all or part of the list of project building elements together with their quantities.
- c) A spreadsheet application is launched which allows the user to add cost data to the building elements. The user will also be able to create cost items which are not directly derived from building element information e.g. preliminaries. Items that need to be costed will be flagged.
- d) The estimator invokes a program to upload the cost data back to the project server.

#### 4.4 CASE 4 - BROWSING DATA THROUGH A VRML AND DWF VIEWER

The user will be able to view building elements through a standard VRML and DWF capable web browser. The user will also be able to select elements and query non-graphical information. System interaction is as follows:

- a) The user accesses and logs in to the project web site using a web browser containing VRML and DWF WHIP plugins.
- b) The user selects an appropriate link on the design page and is presented with a multi frame page, one frame containing a view of the selected design in DWF format.
- c) The user is able to select a building element in VRML and retrieve costing and planning information for the element.

#### 4.5 CASE 5 - PLANNING

This case will allow the planner to program tasks associated with building elements. System interaction is as follows:

- a) The planner accesses and logs in to the project web site using a standard web browser.
- b) The planner navigates to the cost estimating web page and is presented with a choice to retrieve all or part of the list of tasks associated the project building elements.
- c) The system generates a file that can be imported into the user's preferred planning package.
- d) The construction planner uses the facilities of the planning package to schedule the project, calculate critical paths, level resources, etc.
- e) The planner invokes a program to upload the scheduled data back to the project server.

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#### 4.6 CASE 6 – ACCESSING DATA SHEETS

This case will allow a designer to access data sheets on any building elements in a design. System interaction is as follows:

- a) The user accesses and logs in to the project web site using a standard web browser.
- b) The user navigates to the data sheets web page and is presented with a choice of building elements used in the project. Each element appears as a link on the page.
- c) The user selects a given element's link and is presented with data sheets for the element. The sheets will include a link to the manufacturer's web site where applicable.

### 5. IMPLEMENTATION

In this section we report on the implementation of the six cases and how the user specifications are realised. All the applications are designed to interact with a project model. The project model is based on the IFC v1.5 and implemented in an object-oriented database, namely ObjectStore by converting the EXPRESS definition to a set of Java classes.

#### 5.1 IMPLEMENTATION OF CASE-1 - ESTABLISHING A NEW PROJECT DATABASE

The implementation of this task takes advantage of the Internet's open standards and uses the concept of a 'project Web site' as a first point of entry for all shared project information. Each new project has its own Web site (see Figure 2), allowing project information to be accessed through an internal network (Intranet) or through the wider global Internet. Furthermore, existing security mechanisms such as; password protection, certificates, IP address filtering, etc. can be used to ensure the security of the project information by controlling access to the project Web pages.

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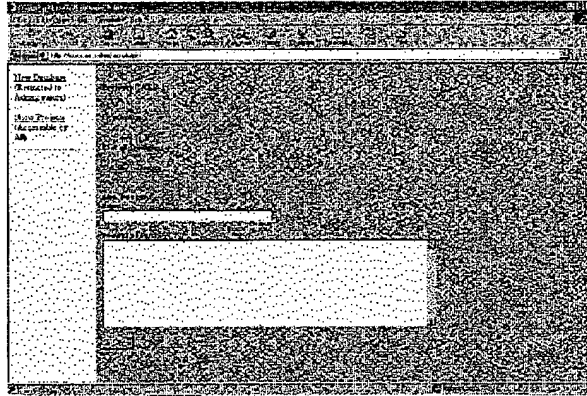


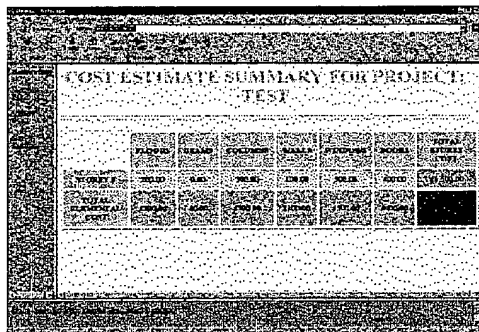
Figure 2: The User Interface

### 5.2 IMPLEMENTATION OF CASE 2 - POPULATING A DATABASE WITH DESIGN INFORMATION

Design is one of the very important applications in a computer-integrated environment. Due to the non-availability of commercial IFC compliant CAD systems, we have implemented our own CAD system that uses AutoCAD-14 geometry engine. Both newly created and existing projects are supported. The application is written in C++. It is anticipated that this application will be replaced by a commercial IFC compliant CAD system. The "newly created project" option enables the user to create new designs and to share information with other construction applications. The design information can also be exchanged with other future CAD commercial systems that support IFC. AutoCAD 14 supports both 2D drafting and solid modelling geometry. The data in our application is saved as a solid model. The format in which the data is saved is STEP Part 21 file. The "existing Project" option of the design application was implemented as a Netscape Web Application Interface (WAI) web server extension. The database is populated by uploading STEP Part 21 file to the design server.

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## 5.3 IMPLEMENTATION OF CASE 3 - COST ESTIMATING



ELEMENT	QUANTITY	UNIT	COST	TOTAL
WALL	100	SQ. FT.	10.00	1000.00
FLOOR	50	SQ. FT.	20.00	1000.00
ROOF	25	SQ. FT.	40.00	1000.00
CEILING	50	SQ. FT.	20.00	1000.00
DOOR	10	EA.	100.00	1000.00
WINDOW	20	EA.	50.00	1000.00
STAIR	10	EA.	100.00	1000.00
ELEVATOR	1	EA.	1000.00	1000.00
MECHANICAL	10	EA.	100.00	1000.00
ELECTRICAL	10	EA.	100.00	1000.00
PLUMBING	10	EA.	100.00	1000.00
PAINT	100	SQ. FT.	10.00	1000.00
LANDSCAPE	10	EA.	100.00	1000.00
TOTAL				10000.00

Figure 3: Cost Summary Presented within the Web Browser.

Estimating is an integrated application that can generate the elemental IFC cost group objects within the central project database from the design, before returning this information into Excel. It is implemented as a WAI web server extension. It starts by identifying all the building elements and their types at each storey of the building e.g. walls, columns, etc. The user add costs to the cost groups in Excel and uploads the CSV file into the project database, i.e. adding costs, date and time, etc. to the automatically generated cost group objects. For each group of elements, the application calculates the individual elemental costs by calculating 1) a unit rate from the element's cost group's cost value and quantity and 2) the quantity of the element. The total costs are calculated for each group of elements at individual storeys, the overall storey, the complete element group, and the project (see Figure 3). The information is uploaded to the estimating server, users such as the project manager, client, etc. have the option to view a cost summary of the project. Finally, a cost summary of the project can be viewed in terms of both element type and storey in HTML format using a web browser.

## 5.4 IMPLEMENTATION OF CASE 4 - BROWSING DATA THROUGH A VRML AND DWF VIEWER

WISPER provides an effective human interface reflecting users' cognitive activities while interacting with the environment. Objects are represented as a three-dimensional data format called VRML. The application generates the VRML model of the design and displays the results within a Web browser automatically and in a manner which is totally transparent to the user. Figure

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4 shows an example of an image of a 3D object visualised VRML on the WISPER clients. Users can change the viewpoint and move the object by using a mouse. Further, information about particular building elements can be obtained on the bottom of the WWW browser by clicking on the element in the virtual world.

Similarly, users can view the design in a DWF (Drawing Web Format) format. DWF is a graphics format for the transfer of drawings over Intranets and the Internet. The application parses the database for the building elements that exist in a project and generates the DWF representation of each element to be displayed on the Web browser. In a similar manner to VRML application, information about individual building elements can be displayed on the bottom of the screen by simply clicking on the required building element.

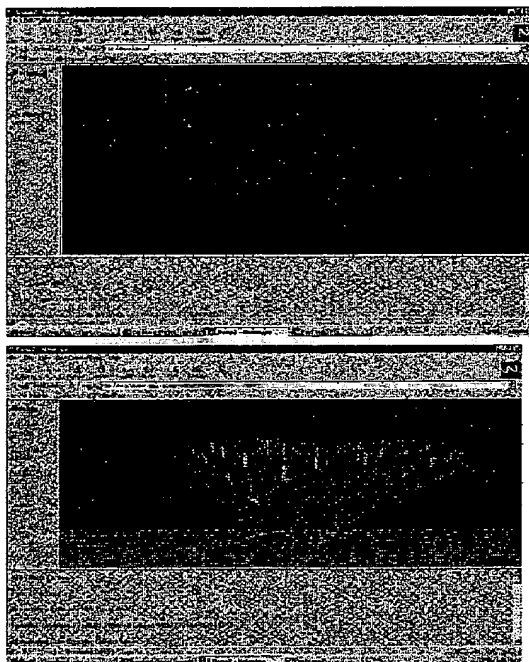


Figure 4: DWF and VRML representation of the design

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## 5.5 IMPLEMENTATION OF CASE 5 - PLANNING

This application generates the work group objects within the central project database from the design, before returning this information into scheduling package - in this project we used MS Project scheduling package. For each group of elements at a particular storey a work group is created, e.g. Construct Walls At Storey 0. Next step requires the user to add duration and links/dependencies to the previously generated work group objects and uploads the CSV file into the project database. Now the information and dependencies are stored in the database which can be downloaded and viewed by the users.

## 5.6 IMPLEMENTATION OF CASE 6 - ACCESSING DATA SHEETS

This web server extension application (WAI) retrieves the information about the building elements with their associated specifications and returns the results to the client web page. This application provides an easy and effective means to view the design and construction data associated with the building elements (see Figure 5).

Figure 5

DOOR LEAF		DOOR FRAME	
Description	Feature Hardwood 6 Panel (762x4x1981)	Description	Fremaster HW Without Sill 829x2016 (89x64)
Manufacturer	Premdor Crosby Ltd	Material	Timber
Material	Timber	Depth	89.0mm
Height	1981.0mm	Thickness	64.0mm
Width	762.0mm		
Fire Rating	0.0hrs		
Thermal Rating	2.65W/m <sup>2</sup> K		
Exterior	TRUE		

Figure 5: Datasheet of the Object "door" in HTML

## 6. Conclusions

This paper has presented the user scenarios of the functionality required in a computer integrated environment. The users' scenario have been captured using Use Case approach. Six cases have been identified. A use case enabled the research team to capture the critical requirements that need to be met by the system. We have reported on the implementation of the six Use Cases which now forms part of the implementation of an integrated multi-user distributed construction project database environment, WISPER. The

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environment is based on a three-tier client-server architecture, the project model is based on the IFC Version 1.5. Web technology was used to develop the user interfaces and enable the communication of distributed applications, i.e. Web pages and Web server extensions, respectively.

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